Uncertainty spreading from kinematics to dynamics in multibody human models

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UNCERTAINTY SPREADING FROM KINEMATICS TO DYNAMICS IN MULTIBODY HUMAN MODELS

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Introduction

The subject-specific model determination is an important component to improve the consistency of the motion analysis results. [1,2] proposed specific dynamic parameters calibration methods based on the minimization of the dynamic error. Indeed, this error depends on the model parameters errors but also on the measurement errors, especially the kinematic one.

In this abstract, we present an adaptation of a Monte Carlo method used to quantify the part due to the kinematic error in the dynamic one. Such information is fundamental to avoid overfitting in model dynamic parameters calibration.

Methods

One subject (1.90m, 67kg) performed a standardized motion recorded by a motion capture system and platform forces.

The multibody human model used for motion analysis was composed of 16 rigid segments linked by 15 joints and exhibited 35 degrees of freedom. A 6 degrees of freedom (DOF) link connected the pelvis to the global reference frame. After a preliminary subject-specific kinematical calibration, body segment inertial parameters were estimated using [3].

Figure 1 shows the pipeline used to analyze the spreading of uncertainty from inverse kinematic results to inverse dynamics ones.

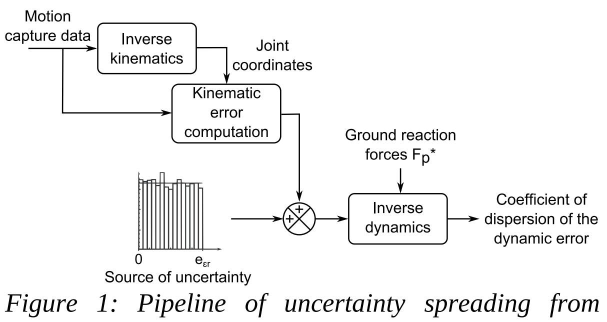

Figure 1: Pipeline of uncertainty spreading from kinematics to dynamics.

Firstly, a source of uncertainty was added on the estimated inverse kinematics results. The measurand of this method was the kinematic error, which corresponds to the average distance between the real and the model markers. We chose to use an uniform distribution over the interval $[0, e_{\varepsilon_r}]$ with e_{ε_r} corresponding to the maximal relative reconstruction error added. Secondly, for this motion, the dynamic error (root-mean-square residual forces in the 6 DOF joint) was computed using the inverse dynamics step.

The N-repetition of these stages allows the analysis of the different coefficient of dispersion.

Results

For each component of the 6DOF joint, the coefficients of dispersion of the dynamic error were evaluated depending on the maximal relative reconstruction error added (e_{ε_r}) (Figure 2). These coefficients of dispersion were compared with the estimated values of the dynamic error (corresponding to the reference dynamic error without any uncertainty addition).

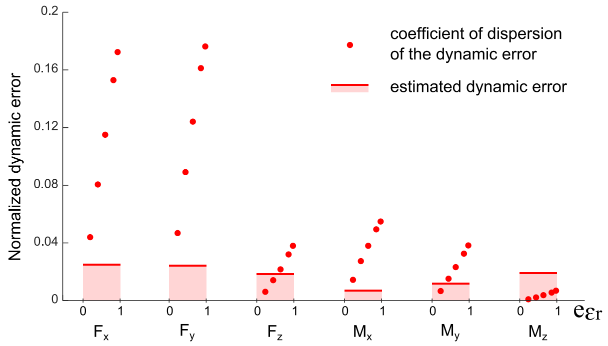

Figure 2: Coefficients of dispersion of the dynamic error and estimated dynamic error.

Discussion

For each component of the 6DOF joint, the spreading of uncertainty between kinematics and dynamics seems to be linear. Then we can assume that the uncertainty due to the kinematic error corresponds to the dynamic coefficient of dispersion obtained with e_{ε_r}=1. Concerning the force components or concerning the moment components, this coefficient of dispersion is widely smaller the vertical axis (z-axis).

Moreover, except for the z-moment component, the uncertainty due to the kinematic error is higher than the estimated value of the dynamic error. Thus, for this subject, the kinematic uncertainty value shows that this is irrelevant to optimize the dynamical parameters of the model. The reason could be that the anthropometric data were close to the specific model parameters of this subject. This preliminary study needs to be generalized with other subjects to allow us defining a relevant stop criterion for a model dynamic parameters calibration.

References

1. Hansen et al, J Biomech, 47(7), 1577-1581, 2014.
2. Reinbolt et al, Bio Engineering, IEEE Transactions, 54(5), 782-793, 2007.
3. Dumas et al, J Biomech, 40(3), 543-553, 2007.